Environmental Technology Verification Program Protocol

Generic Verification Protocol for Dust Suppression and Soil Stabilization Products

Prepared by
Research Triangle Institute

Under a Cooperative Agreement with
U.S. Environmental Protection Agency

RTI International is a trade name of Research Triangle Institute.
GENERIC VERIFICATION PROTOCOL FOR
DUST SUPPRESSION AND SOIL
STABILIZATION PRODUCTS

EPA Cooperative Agreement Nos. CR826152-01-3 and CR831191-10-1

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Notice

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# ACRONYMS AND ABBREVIATIONS

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>AASHTO</td>
<td>American Association of State Highway and Transportation Officials</td>
</tr>
<tr>
<td>ADQ</td>
<td>audit of data quality</td>
</tr>
<tr>
<td>ANSI</td>
<td>American National Standards Institute</td>
</tr>
<tr>
<td>APCT</td>
<td>air pollution control technology</td>
</tr>
<tr>
<td>APCTVC</td>
<td>Air Pollution Control Technology Verification Center</td>
</tr>
<tr>
<td>ASCE</td>
<td>American Society of Civil Engineers</td>
</tr>
<tr>
<td>ASQ (or ASQC)</td>
<td>American Society for Quality</td>
</tr>
<tr>
<td>ASTM</td>
<td>American Society for Testing and Materials</td>
</tr>
<tr>
<td>BOD</td>
<td>biological oxygen demand</td>
</tr>
<tr>
<td>CBR</td>
<td>California bearing ratio</td>
</tr>
<tr>
<td>CE</td>
<td>control efficiency</td>
</tr>
<tr>
<td>CERF</td>
<td>Civil Engineering Research Foundation</td>
</tr>
<tr>
<td>CH</td>
<td>fat clay</td>
</tr>
<tr>
<td>CL</td>
<td>inorganic clay of low to medium plasticity; sandy, silty, or lean clay</td>
</tr>
<tr>
<td>cm</td>
<td>centimeter(s)</td>
</tr>
<tr>
<td>CO₂</td>
<td>carbon dioxide</td>
</tr>
<tr>
<td>COD</td>
<td>chemical oxygen demand</td>
</tr>
<tr>
<td>CVP</td>
<td>cumulative vehicle passes</td>
</tr>
<tr>
<td>DQO</td>
<td>data quality objective</td>
</tr>
<tr>
<td>EPA</td>
<td>U.S. Environmental Protection Agency</td>
</tr>
<tr>
<td>ETV</td>
<td>Environmental Technology Verification Program</td>
</tr>
<tr>
<td>EvTEC</td>
<td>Environmental Technology Evaluation Center</td>
</tr>
<tr>
<td>FIFRA</td>
<td>Federal Insecticide, Fungicide and Rodenticide Act</td>
</tr>
<tr>
<td>FLW</td>
<td>Fort Leonard Wood, MO</td>
</tr>
<tr>
<td>g</td>
<td>gram(s)</td>
</tr>
<tr>
<td>GC</td>
<td>gray calcareous gravel/sand/clay mixture</td>
</tr>
<tr>
<td>GM</td>
<td>gray calcareous gravel/sand/silt mixture</td>
</tr>
<tr>
<td>GP</td>
<td>poorly graded gravel, gravel/sand mixture, little or no fine</td>
</tr>
<tr>
<td>GW</td>
<td>well-graded gravel, gravel/sand mixture, little or no fine</td>
</tr>
<tr>
<td>GVP</td>
<td>generic verification protocol</td>
</tr>
<tr>
<td>HAP</td>
<td>hazardous air pollutant</td>
</tr>
<tr>
<td>HITEC</td>
<td>Highway Innovative Technology Evaluation Center</td>
</tr>
<tr>
<td>hr</td>
<td>hour(s)</td>
</tr>
<tr>
<td>IFR</td>
<td>isokinetic flow ratio</td>
</tr>
<tr>
<td>ISO</td>
<td>International Organization for Standardization</td>
</tr>
<tr>
<td>km</td>
<td>kilometer(s)</td>
</tr>
<tr>
<td>l</td>
<td>liter(s)</td>
</tr>
<tr>
<td>LC₅₀</td>
<td>Lethal Concentration 50 is the concentration of a chemical which kills 50% of a sample population.</td>
</tr>
<tr>
<td>m</td>
<td>meter(s)</td>
</tr>
<tr>
<td>mg</td>
<td>milligram(s)</td>
</tr>
<tr>
<td>MH</td>
<td>inorganic silt; micaceous or diatomaceous, fine, sandy or silty soil; elastic silt</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
</tr>
<tr>
<td>--------------</td>
<td>-------------</td>
</tr>
<tr>
<td>ML</td>
<td>inorganic silt and very fine sand, silty/clayey fine sand</td>
</tr>
<tr>
<td>mph</td>
<td>miles per hour</td>
</tr>
<tr>
<td>MRI</td>
<td>Midwest Research Institute</td>
</tr>
<tr>
<td>NVP</td>
<td>number of vehicle passes</td>
</tr>
<tr>
<td>OECD</td>
<td>Organization for Economic Cooperation and Development</td>
</tr>
<tr>
<td>OH</td>
<td>fat organic clay</td>
</tr>
<tr>
<td>OL</td>
<td>organic silt and organic silty clay of low plasticity</td>
</tr>
<tr>
<td>PAH</td>
<td>polycyclic aromatic hydrocarbon</td>
</tr>
<tr>
<td>PEA</td>
<td>performance evaluation audit</td>
</tr>
<tr>
<td>PM</td>
<td>particulate matter</td>
</tr>
<tr>
<td>PM₁₀</td>
<td>particulate matter 10 micrometers or less in aerodynamic diameter</td>
</tr>
<tr>
<td>PM₂.₅</td>
<td>particulate matter 2.5 micrometers or less in aerodynamic diameter</td>
</tr>
<tr>
<td>PT</td>
<td>peat, humus, and other organic swamp soil</td>
</tr>
<tr>
<td>QA</td>
<td>quality assurance</td>
</tr>
<tr>
<td>QC</td>
<td>quality control</td>
</tr>
<tr>
<td>QMP</td>
<td>quality management plan</td>
</tr>
<tr>
<td>RCRA</td>
<td>Resource Conservation and Recovery Act</td>
</tr>
<tr>
<td>RDS</td>
<td>relative standard deviation</td>
</tr>
<tr>
<td>RTI</td>
<td>Research Triangle Institute</td>
</tr>
<tr>
<td>s</td>
<td>second(s)</td>
</tr>
<tr>
<td>SC</td>
<td>clayey sand, sand/silt mixture</td>
</tr>
<tr>
<td>SM</td>
<td>silty sand, sand/silt mixture</td>
</tr>
<tr>
<td>SOP</td>
<td>standard operating procedure</td>
</tr>
<tr>
<td>SP</td>
<td>poorly graded sand, gravelly sand, little or no fine</td>
</tr>
<tr>
<td>SW</td>
<td>well-graded sand, gravelly sand, little or no fine</td>
</tr>
<tr>
<td>TCLP</td>
<td>Toxicity Characteristics Leaching Procedure</td>
</tr>
<tr>
<td>TIC</td>
<td>tentatively identified compound</td>
</tr>
<tr>
<td>T/QAP</td>
<td>test/quality assurance plan</td>
</tr>
<tr>
<td>TP</td>
<td>technical panel</td>
</tr>
<tr>
<td>TSA</td>
<td>technical systems audit</td>
</tr>
<tr>
<td>TSCA</td>
<td>Toxic Substances Control Act</td>
</tr>
<tr>
<td>TSP</td>
<td>total suspended particulate</td>
</tr>
<tr>
<td>USCS</td>
<td>Unified Soil Classification System</td>
</tr>
<tr>
<td>VKT</td>
<td>vehicle kilometers traveled</td>
</tr>
<tr>
<td>VOC</td>
<td>volatile organic compound</td>
</tr>
<tr>
<td>vpd</td>
<td>vehicles per day</td>
</tr>
<tr>
<td>µg</td>
<td>microgram(s)</td>
</tr>
<tr>
<td>µm</td>
<td>micrometer(s)</td>
</tr>
</tbody>
</table>
1.0 BACKGROUND

This generic verification protocol, developed through the Environmental Technology Verification (ETV) program of the U.S. Environmental Protection Agency (EPA), describes the nature and scope of tests to verify the performance and environmental impacts of dust suppression and soil stabilization products. This section of the protocol provides background on the ETV program, the reason and purpose for this protocol, the partnership behind the development of this protocol, and testing and quality management processes under this protocol.

1.1 Description of the ETV Program

The ETV program was established to develop testing protocols and verify the performance of innovative technologies that have the potential to improve protection of human health and the environment. ETV operates as a public-private partnership through agreements between EPA and private testing and evaluation organizations. These ETV verification organizations work with EPA technology experts to create efficient and fully quality-assured testing procedures that verify the performance of innovative technologies. ETV now operates six centers and one pilot program, which cover a broad range of environmental technology categories. Vendors and others in the private sector—as well as federal, state and local government agencies—cost-share with EPA in order to complete priority ETV protocols and verifications.

The ETV goal is to provide credible performance data for commercial-ready technologies to speed their implementation for the benefit of vendors, purchasers, permitters, and the public.

1.2 Reason for the Dust Suppression and Soil Stabilization Testing Program

In the United States alone, there are more than 2.4 million km of unpaved roads and streets. Unpaved mileage can include graded and drained roadways made of natural earth, gravel, stone, slag, shell, or similar materials. These roadways are often aligned and graded to permit use by motor vehicles. In addition, there are thousands of kilometers of unpaved areas such as construction sites, parks, parking lots, racing tracks, and mines. Two of the most prevalent problems associated with unpaved roads are (i) controlling traffic-generated dust and (ii) maintaining stability of roads throughout the year.

Traffic-generated dust from unpaved roads contributes significantly to exceedances of ambient air quality standards for particulate matter, a cause of respiratory problems. These airborne particulates also degrade agricultural produce, increase wear and tear on vehicles, and result in a higher rate of deterioration of the roadway. Reducing dust improves drivers’ sight distance, reduces effects on adjacent roadside stream habitats, decreases the roadway maintenance needed to improve ride quality, and decreases the loss of surface aggregate.

The strength of unpaved roads undergoes significant fluctuations during the year due to the continuous variations in soil conditions. Stability and load-bearing capacity of unpaved roads depend mainly on the shear strength of soil, which in turn depends on the type of soil. Adverse climatic and loading conditions, such as freeze-thaw variations and alternating dry-out shrinkage
and wetting/swelling, can result in the formation of waves, transverse corrugations (washboarding), rutting, and shoving.\textsuperscript{5}

In recent years, advances have been made in the dust suppressant and soil stabilization industry, and new products have hit the market. This protocol calls for high-quality field evaluations of these products, conducted for a range of soil types, environmental conditions, traffic, and other factors that are needed to demonstrate the performance of the available products. This protocol also calls for laboratory analyses of these products. It is based on expert opinions, as expressed by the members of two expert panels, that address the concerns of users and manufacturers/vendors of these products and of environmental regulators.

The test data will be reported in an ETV Verification report and a summary ETV Verification statement, which will be made available to federal, state, and local highway agencies, environmental regulators, and others who may use or assess the use of these products.

1.3 **Purpose of This Protocol**

This generic verification protocol (GVP) describes the nature and scope of tests to verify the performance and the environmental impacts of dust suppression and soil stabilization products. The primary performance measures for dust suppression products are (i) percent control of dust that contributes to air pollution and (ii) roadway performance of the products with respect to maintenance. The primary performance measure for the soil stabilization products is stability of soil on the roadway. A number of government agencies have expressed a desire to have performance and baseline environmental data collected on these products. The agencies want this information to make some initial inferences about the products’ performance and potential impacts on local waterways, soils, and plant and animal life.

This protocol contains descriptions of the following:

- Project organization and responsibilities of parties involved in the ETV evaluation;
- Objectives of the evaluation;
- Tables summarizing laboratory analyses, methods, and matrices on which they are performed;
- Sampling methods for the products; and
- Planning, reporting, and documentation.

Test/quality assurance plans (T/QAPs) will be written for testing at each specific site. All ETV testing will be conducted following the EPA and Research Triangle Institute (RTI) ETV policies in place at the time of the testing.

1.4 **Development of This Protocol**

The initial version of this protocol was developed by the Air Pollution Control Technology (APCT) Verification Center (APCTVC), the Environmental Technology Evaluation Center (EvTEC), and the Highway Innovative Technology Evaluation Center (HITEC). It was prepared with input from two technical panels (TPs) and approval by EPA. APCTVC is a center of the
EPA’s ETV Program. EPA’s partner in APCTVC is RTI, a nonprofit research organization. EvTEC and HITEC were two Innovation Centers within the Civil Engineering Research Foundation (CERF), the research and technology transfer arm of the American Society of Civil Engineers (ASCE).

1.5 Testing and Quality Management

In general, the organizations that will carry out the verification of dust suppressants and soil stabilizers include ETV verification organizations, testing organizations, and laboratories. ETV verification organizations oversee all aspects of the ETV verification—including preparation and review of the GVPs and T/QAPs, oversight of testing organizations, and development of ETV verification reports. The verification organization involved in this ETV verification is APCTVC (RTI). Testing organizations are responsible for assisting in preparation of GVPs, preparing T/QAPs, conducting testing or overseeing the collection of test data, and writing ETV verification reports. The testing organization involved in this ETV verification is Midwest Research Institute (MRI). Laboratories analyze testing samples and may be independent contractors or organizations that are part of the ETV verification (e.g., both RTI and MRI have laboratory capabilities). Additional testing organizations and laboratories may be contracted as necessary.

With the support of MRI, RTI has developed this ETV verification test protocol for dust suppression and soil stabilization products and prepared specific T/QAPs, conducted independent testing of these products, and prepared ETV verification test reports and statements for broad dissemination. All site- or product-specific information addressed in conducting ETV verification testing has been covered in the T/QAPs, which provide a detailed plan for implementing each ETV verification test and document test procedures.

Management and testing based on this protocol are performed in accordance with procedures and protocols defined by a series of quality management documents. These include

- EPA’s Quality and Management Plan for ETV\(^6\) (ETV QMP),
- Quality Management Plan (QMP) for APCTVC,\(^7\)
- GVP for Dust Suppression and Soil Stabilization Products (this document), and
- T/QAPs prepared by the test organizations.

EPA’s **ETV QMP** provides definitions, procedures, processes, interorganizational relationships, and outputs that will ensure the quality of both the data and the programmatic elements of ETV. Part A of the ETV QMP contains the specifications and guidelines that are applicable to common or routine quality management functions and activities necessary to support the ETV. Part B of the ETV QMP contains the specifications and guidelines that apply to test-specific environmental activities involving the generation, collection, analysis, evaluation, and reporting of test data.

The **APCTVC’s QMP** describes the quality systems in place for APCTVC. It was prepared by RTI and approved by EPA. Among other quality management items, it defines what must be covered in the GVPs and T/QAPs for products/technologies undergoing ETV verification testing.
The document herein is the **GVP for Dust Suppression and Soil Stabilization Products**. It is a single GVP prepared for all of the dust suppression and soil stabilization products to be verified. It describes the general procedures to be used for testing a product and defines the projected critical data quality objectives (DQOs).

The pertinent T/QAPs will be prepared by the test organizations. A T/QAP describes, in detail, how the testing organization will implement and meet the requirements of the GVP. Meeting EPA requirements for quality assurance plans, the T/QAP addresses issues such as the test organization’s management structure, as well as major lines of communication in the testing organization and with any other test participants. The plan provides a table listing the name, affiliation, mailing address, telephone and fax numbers, and e-mail address of each participant; test schedule; test documentation; analytical methods; data collection requirements; instrument calibration and traceability; site; and product application. It also specifies the QA and quality control (QC) requirements for obtaining ETV verification data of sufficient quantity and quality to satisfy the DQOs of the GVP. Section 7.0 of this GVP addresses requirements for the T/QAP.

### 2.0 ETV PROJECT ORGANIZATION AND RESPONSIBILITIES

The organization within which the ETV verification test activities will be conducted and the roles and responsibilities of the principal parties are described below.

#### 2.1 Organization

RTI’s APCTVC Director is Mr. Andrew Trenholm. The Task Leader is Ms. Deborah Franke. Dr. C.E. Tatsch is RTI’s Quality Manager for APCTVC. At MRI, Mr. John Hosenfeld is Task Leader and Mary Ann Grelinger is Task Quality Manager. Mr. Michael Kosusko is the EPA Program Manager for APCTVC. Mr. Paul Groff is EPA’s Quality Manager for APCTVC.

The final version of the ETV verification statement will be approved and signed by the director of EPA’s National Risk Management Research Laboratory and Mr. Trenholm of RTI.

#### 2.2 Roles and Responsibilities

ETV testing will be conducted by APCTVC under the sponsorship of EPA. Participation of product manufacturers/vendors is integral to ETV verification testing. APCTVC is operated under a cooperative agreement between EPA and RTI. Subcontractors have roles in APCTVC under RTI’s management. In particular, MRI is the testing organization designated to conduct testing under APCTVC.

The primary responsibilities for the organizations involved in the ETV test program are as follows:

1. EPA, following its procedures for ETV, reviews and approves GVPs, T/QAPs, and ETV verification reports and statements.

2. The TP reviews and provides guidance and comment on the GVP.
3. APCTVC prepares the GVP, with support from MRI.

4. The testing organizations prepare the T/QAPs, conduct the tests, and prepare the verification reports.

5. APCTVC reviews the T/QAPs, and, jointly with EPA, reviews and approves the ETV verification test reports and statements.

6. APCTVC may identify and secure testing sites; however, vendors obtain approval for testing at sites where their products/technologies will be in commercial use.

7. APCTVC provides oversight of its contracted testing and laboratory organizations.

8. Laboratories perform tests according to the test methods specified in the protocol and the T/QAP. Laboratories are expected to operate under their own quality systems.

9. The QA staff of APCTVC conducts technical assessments according to the T/QAP of the test and of the laboratory organization’s tests and products.

10. The product manufacturers/vendors are responsible for providing their products ready for verification testing, providing the equipment and labor to apply the products, making specific application arrangements with the site owner, and arranging other logistical and technical support as required to assist the testing organization during the verification testing. APCTVC provides access to the test site and requires that each manufacturer/vendor provide a written application plan for their product(s) covering the test period. The application plan must describe how the suppressant and/or stabilizer will be prepared or mixed and applied as well as any preparation of the road surface before application, and the recommended frequency of applications. Each manufacturer/vendor must supply a verifiable description of the product to be tested and its performance capability. Each manufacturer/vendor will be responsible for bearing all or a portion of the test cost as defined by the contract or letter of agreement with RTI.

11. APCTVC prints and distributes the published documents according to its processes. See Section 5.0 for details on reporting.

3.0 OBJECTIVES AND SCOPE

3.1 Objective

The objective of the dust suppression and soil stabilization ETV verification is to verify the performance of the tested product relative to the set of meaningful criteria (described in Section 4.0 of this GVP) established by the technical panels and accepted by the manufacturer/vendor.

3.2 Scope

Testing will be performed on areas where dust suppression and soil stabilization products have been applied. The ETV verification tests will gather information and data for evaluating the
performance of the products and the products’ associated environmental impacts and resource requirements. The scope will, in most cases, cover four principal study questions:

1. What is the performance of the product with respect to air quality, functional roadway performance and maintenance, and soil stability (e.g., PM$_{2.5}$ control efficiency in percent and/or dynamic cone penetrometer results) over time?

2. Over what range of test conditions is the performance measured (e.g., road conditions, atmospheric and climatic conditions, weather seasons, vehicle traffic)?

3. What are the associated environmental impacts of using the product under the test conditions (e.g., water quality impact, hazardous characteristics, safety)?

4. What are the resources associated with using the product under the test conditions (e.g., product usage, labor for application, maintenance, and monitoring)?

3.3 Products to be Tested

3.3.1 Dust Suppressants

Dust suppressants are products formulated to reduce dust emissions from unpaved surfaces. Over the years, many dust suppressants have been developed to contain dust on unpaved roads. Dust suppressants are designed to alter the roadway by lightly cementing the particles together, either by increasing the particles’ weight so that they are less likely to move under traffic or wind, or by forming a surface that attracts and retains moisture. Generally, they are applied to the road surface in a water solution, which dries on the surface of the road and reduces the dust created by vehicles and wind. How much dust control is achieved depends on the following$^{9,10}$:

- Application intensity (volume of the solution per unit area);
- Product dilution ratio;
- Frequency (number of applications) of the solution’s application to the surface;
- Interaction with the surface material;
- Atmospheric and climatic conditions;
- Type (weight, wheeled or tracked, number of axles, etc.), number, and velocity of vehicles using the road, as well as road geometry.

3.3.2 Soil Stabilizers

If the stability of local soil is not adequate for supporting wheel loads, its properties can be improved using suitable stabilizing agents. Soil stabilizers coat individual particles and use physical, physiochemical, and/or chemical methods to alter the soil’s properties. Soil stabilization may result in any one or more of the following changes:$^5$

- Increase in soil stability,
- Change in soil density,
- Change in soil swelling,
- Change in other physical characteristics,
• Change in soil’s chemical properties,
• Retention of the desired minimum strength by waterproofing,
• Lower aggregate replacement costs,
• Lower grading costs, and
• Increased traction of wheeled vehicles.

3.4 Data Quality Objectives (DQOs)

3.4.1 DQO for Dust Suppression

Product performance is the major determinant of the absolute magnitude of control efficiency (CE); however, CE is also influenced by climate and road characteristics. Climate will vary throughout the test and both climate and road characteristics will vary with the location of the test site. Neither of these factors can be controlled to provide standardization of their effects on the measured product performance. CE values will be provided; however, their primary value is to distinguish differences in product performance at a given test location, e.g., at different times after application. Thus, the DQO focuses on the variability of the mobile sampler measurements, expressed in terms of CE. It does not include uncertainty in the magnitude of the CE associated with the equation developed to correlate the mobile sampler results with the more established procedure of profiling.

The DQO varies with CE and is expressed in percent as the half-width interval for the 90 percent confidence limits. Use of a 90 percent confidence limit was judged appropriate for open-source dust emission measurements that are subject to greater inherent variability than many environmental measurements. When a full year (four quarters) of data is available, the DQO is set at (100 - CE)/5. When fewer quarters of data are available, it is adjusted higher. Appendix A describes the DQO and its calculation for a year-long test. For a specific test, the test plan will provide a DQO appropriate to the length of the test.

3.4.2 DQO for Dust Suppression Functional Performance

For the dust suppression functional performance, a DQO is being applied to the product’s dust CE using the dustometer developed by Colorado State University. The use of this instrument is described in a paper by Sanders et al10. After each testing period, two or three emission measurements will be taken. The following DQO will be applied:

• The standard deviation for the mean of the emissions measurements from any one testing period should be 25% or less.

3.4.3 DQO for Soil Stabilization Performance

For the soil stabilization performance, a DQO is being applied to the measurement of the load-bearing capacity of treated materials to evaluate the product’s ability to bind the soils. During the ETV verification test program, one set of laboratory tests will be conducted on the load bearing capacity of the products. The following DQO will be applied:

• California bearing ratio (CBR) measurements will be made in accordance with American Society for Testing and Materials (ASTM) Test Method D1883-99 Standard Test Method for
CBR of Laboratory- Compacted Soils and in accordance with ASTM Practice D3740-01 Standard Practice for Minimum Requirements for Agencies Engaged in the Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction and will have the accuracy required for those standards.

4.0 TEST PROGRAM

The objective of ETV verification testing is to evaluate the performance of products relative to a set of meaningful criteria established by an expert TP and agreed to by the manufacturer/vendor. (While the ETV is not regulatory and an ETV test is not a compliance test, measurements that relate to regulations are of primary interest to most manufacturers/vendors and potential users.) Also, the environmental impacts of using the product and the energy and environmental resource requirements must be evaluated. Conditions during testing must be documented as part of the ETV verification process.

The two sections below will discuss the overall test design to achieve the ETV verification objectives, followed by a discussion of test parameters. Detailed descriptions and a schedule for the preparation, conduct, and reporting related to the test design must be given in the T/QAP.

4.1 Test Design

An ETV verification test must be designed to determine the performance of a dust suppressant or soil stabilizer in specified terms and of known quality and to define the applicability bounds of the verification. Four major factors to consider in the test design for dust suppression and soil stabilization are

- Test site characteristics, including test locations, activities at the site, and atmospheric and climatic conditions;
- Sample locations and sampling and measurement methods;
- Product application method, quantity, and frequency; and
- Number, frequency, and duration of measurements.

4.1.1 Test Site Characteristics

The characteristics of the test road selected are important in designing the test program and selecting the sample locations and sampling and measurement methods. The following are desired characteristics of the test road:

- A section must be available to remain untreated (control section).
- Test roads must be relatively long and straight for concurrent testing with lengths for each product to be applied as specified below:
  - a minimum of 150 m for each test section for mobile dust sampling, and
  - approximately 0.8 to 1.6 km for each test section for soil stabilization and dustometer testing.
- For air pollutant emissions sampling, significant upwind particulate emission sources must not be present in the immediate vicinity (≤150 m) of any test section.
• Traffic should be representative of normally occurring traffic.
• The traffic rate should be high enough during sampling to complete each sampling event in 1 to 3 hr.\textsuperscript{13}

Note that the above refer to test road characteristics; additional measurement-specific conditions are given in Section 4.2.

If multiple products are to be evaluated at a single test location, the test road(s) must be long enough to accommodate a test section for each product tested plus one additional section that will be left untreated throughout the program. This approach will require 0.8 to 1.6 km test sections for each product and an uncontrolled section when mobile dust sampling and soil stabilization tests are conducted. The chosen roads should be similar in construction and traffic.

The type of soil to be treated will be grouped into five classes according to the Unified Soil Classification System (USCS)\textsuperscript{14} as follows:

• Gravels (GW, GP, GM, GC),
• Sands (SW, SP, SM, SC),
• Silts and clays (ML, CL, OL),
• Silts and clays (MH, CH, OH), and
• Highly organic soils (PT).

Before any testing, the road must not be visibly wet, and no measurable precipitation shall have occurred in the preceding 12 hours. Atmospheric and climatic conditions will also be categorized as wet-freeze, dry-freeze, wet-no-freeze, and dry-no-freeze. Before applying the product, soil samples will be collected and a series of tests will be conducted on the untreated road to establish an average untreated emission factor for the unpaved road. Also, these untreated tests will indicate if emission characteristics of the test sections are substantially different. To ensure that all roads to be included in a test are equal, only untreated road surfaces will be used for the test.

The traffic on the road must be considered when designing the test program. For test roads in industrial settings, using the “naturally occurring” traffic is preferred to aging (i.e., decay) the applied product over time. The type of traffic and the average vehicle speed significantly influence the effectiveness of the treatment applied. For simplicity, the automobile and truck traffic may be combined into one unit based on passenger car unit or equivalent single-axle unit values or any other appropriate procedure. Traffic will be expressed in terms of average traffic per day as low (0 to 50 vehicles per day [vpd]), moderate (50 to 200 vpd), or high (greater than 200 vpd). When conducting profiling tests, however, the natural traffic volume may not be too high to complete tests within a reasonable period of time. In that case, “captive” traffic that mimics the characteristics (speed, weight) of the natural traffic will be used.

4.1.2 Measurement Methods

Tables 1 through 6 list all the measurements to be performed during an ETV verification test and their measurement methods. These methods will be used as appropriate, depending on whether dust suppression, soil stabilization, or both performance criteria are selected for a test. The T/QAP will provide detailed information on all measurements planned for a test.
4.1.3 Product Application

An important part of a verification test is documenting the method by which a product is applied. The performance of a dust suppressant and/or soil stabilizer may be affected by the way in which it is applied. Therefore, the recommended option is to have a product applied as it would normally be distributed or applied by the manufacturer/vendor. The manufacturer/vendor must provide a product application plan to APCTVC prior to application, and apply (or supervise application of) the product according to the plan. The ETV testing organization will observe and document the product application and compare it with the application plan.

The T/QAP will document the location of each test subsection for each product and the application procedures provided by the manufacturers/vendors. Proper documentation of issues relating to construction, materials used, placement techniques, environmental conditions at the time of construction, time required for each operation, roadway characteristics, and traffic will be documented. Proper identification marks will be made in the field to enable engineers/technicians to locate the test sections for subsequent monitoring. Site operations will be extensively photographed during each evaluation for future reference. Frequent local observation of the test site will indicate if there are any unintended changes in the road while testing is in progress.

Manually cleaning buffers (with soft-bristle brooms and/or water flushing) is important to ensure that material is not tracked from one test surface to another. Buffers are formed by heavily applying excess products at the edges of test sections. Buffers are usually less than 16 m in total length along the road centerline, and the application of product is typically two or three times greater than for the test section itself. Furthermore, the products can overlap on buffers—e.g., if a section and buffer are treated with product A on a Friday, then the same buffer may be treated with product B on the following Tuesday when the test section for product B is treated. This provides a very heavily controlled surface that can be readily cleaned to avoid cross-contamination between test sections.

Table 1. Performance Factor Parameters Measured During Verification Test Program

<table>
<thead>
<tr>
<th>Factors to be Verified</th>
<th>Parameter to be Measured</th>
<th>Measurement Method</th>
<th>Frequency</th>
<th>Program&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dust suppressant control efficiency</td>
<td>Uncontrolled dust emissions</td>
<td>Mobile dust sampler&lt;sup&gt;9&lt;/sup&gt;</td>
<td>Quarterly&lt;sup&gt;b&lt;/sup&gt; (replicates)</td>
<td>E</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Controlled dust emissions</td>
<td>Mobile dust sampler&lt;sup&gt;9&lt;/sup&gt;</td>
<td>Quarterly&lt;sup&gt;b&lt;/sup&gt; (replicates)</td>
<td>E</td>
<td></td>
</tr>
<tr>
<td>Soil stabilization effect</td>
<td>Load bearing capacity of soil (controlled and uncontrolled sections)</td>
<td>Dynamic cone penetrometer or California bearing ratio (CBR) D4429&lt;sup&gt;15&lt;/sup&gt;</td>
<td>Quarterly&lt;sup&gt;b&lt;/sup&gt;</td>
<td>S</td>
<td>ASTM D4429&lt;sup&gt;15&lt;/sup&gt; FHW A-HI93-056&lt;sup&gt;16&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup> Program types are dust emissions (E), functional performance (F), and soil stabilization (S).

<sup>b</sup> Quarterly tests occur at the end of each quarter after application. The actual date will be determined by agreement of the parties, and will be dependent upon weather.
## Table 2. Associated Impact Parameters Measured During Dust Suppression and Soil Stabilization Verification Test Program

<table>
<thead>
<tr>
<th>Factors to be Verified</th>
<th>Parameter to be Measured</th>
<th>Measurement Method</th>
<th>Frequency</th>
<th>Program&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative effectiveness of dust suppression</td>
<td>Dust emission</td>
<td>Colorado State University - Dustometer&lt;sup&gt;10&lt;/sup&gt; or similar device</td>
<td>Quarterly&lt;sup&gt;b&lt;/sup&gt;</td>
<td>F</td>
<td>Sanders, et al.&lt;sup&gt;10&lt;/sup&gt;</td>
</tr>
<tr>
<td>Dust suppressant control efficiency</td>
<td>Uncontrolled dust emissions</td>
<td>Exposure profiling&lt;sup&gt;17&lt;/sup&gt;</td>
<td>Optional (quarterly&lt;sup&gt;b&lt;/sup&gt;)</td>
<td>E</td>
<td>May be used in addition to mobile dust sampler technique.</td>
</tr>
<tr>
<td></td>
<td>Controlled dust emissions</td>
<td>Exposure profiling&lt;sup&gt;17&lt;/sup&gt;</td>
<td>Optional (quarterly&lt;sup&gt;b&lt;/sup&gt;)</td>
<td>E</td>
<td></td>
</tr>
<tr>
<td>Soil stabilization effect</td>
<td>Load bearing capacity of treated soil</td>
<td>California bearing ratio (CBR), ASTM D-1883&lt;sup&gt;11&lt;/sup&gt;</td>
<td>Once&lt;sup&gt;c&lt;/sup&gt; (laboratory)</td>
<td>S</td>
<td>Test is conducted on treated soil under laboratory conditions.</td>
</tr>
<tr>
<td></td>
<td>Loss of treated materials from road</td>
<td>Elevations</td>
<td>Quarterly&lt;sup&gt;b&lt;/sup&gt;</td>
<td>F,S</td>
<td>Several measurements are taken across the road. A comparison is made between before and after application.&lt;sup&gt;10&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup> Program types are dust emissions (E), functional performance (F), and soil stabilization (S)

<sup>b</sup> Quarterly tests occur at the end of each quarter after application. The actual date will be determined by agreement of the parties, and will be dependent upon weather.

<sup>c</sup> Measurements will be done once at the time of (and prior to) the first application.

## Table 3. Associated Impacts of Using the Products - Environmental and Toxicological Tests<sup>a</sup>

<table>
<thead>
<tr>
<th>Factors to be Verified</th>
<th>Parameter to be Measured</th>
<th>Measurement Method</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole effluent toxicity 40 CFR Part 13617</td>
<td>Acute toxicity of product</td>
<td>EPA/600/4-90/027&lt;sup&gt;19&lt;/sup&gt;</td>
<td>Water fleas lethal concentration 50 (LC&lt;sub&gt;50&lt;/sub&gt;) Fathead minnow LC&lt;sub&gt;50&lt;/sub&gt; Mysid shrimp LC&lt;sub&gt;50&lt;/sub&gt;</td>
</tr>
<tr>
<td></td>
<td>Chronic toxicity of product</td>
<td>EPA/600/4-91/00&lt;sup&gt;20&lt;/sup&gt;</td>
<td>Water fleas LC&lt;sub&gt;50&lt;/sub&gt; Fathead minnow LC&lt;sub&gt;50&lt;/sub&gt; Mysid shrimp LC&lt;sub&gt;50&lt;/sub&gt;</td>
</tr>
<tr>
<td>Biochemical oxygen demand (BOD) of product</td>
<td>5-day BOD</td>
<td>EPA Method 405.1&lt;sup&gt;21&lt;/sup&gt;</td>
<td></td>
</tr>
</tbody>
</table>
### Table 4. Associated Impacts of Using the Products –Toxicological and Environmental Tests

<table>
<thead>
<tr>
<th>Factors to be Verified</th>
<th>Parameter to be Measured</th>
<th>Measurement Method</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terrestrial toxicity</td>
<td>Product toxicity</td>
<td>EPA Guideline 850.2200&lt;sup&gt;25&lt;/sup&gt;</td>
<td>Ingestion and drinking</td>
</tr>
<tr>
<td>Insect toxicity</td>
<td>Product toxicity</td>
<td>EPA Guideline 850.3020&lt;sup&gt;26&lt;/sup&gt;</td>
<td>Dermal contact - insect/pollinator</td>
</tr>
<tr>
<td>Vegetation toxicity</td>
<td>Product toxicity</td>
<td>EPA Guideline 850.4000&lt;sup&gt;27&lt;/sup&gt;</td>
<td>Direct contact - vegetation</td>
</tr>
<tr>
<td>Algal toxicity</td>
<td>Product toxicity</td>
<td>EPA Guideline 850.4400&lt;sup&gt;28&lt;/sup&gt;</td>
<td>Aquatic plant</td>
</tr>
<tr>
<td>Biodegradability of product</td>
<td>CO₂ evolution</td>
<td>Organization for Economic Cooperation and Development (OECD) Method 301B&lt;sup&gt;29&lt;/sup&gt;</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup> Tests listed would only be conducted once for each product, even if the product is tested at multiple test sites. The product will be sampled at the time of application. A company may submit results of previous tests.
Table 5. Associated Resource Usage Parameters Measured During Verification Test Program

<table>
<thead>
<tr>
<th>Factors to Be Verified</th>
<th>Parameter to Be Measured</th>
<th>Measurement Method</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product application intensity</td>
<td>Number of test pans</td>
<td>Recordkeeping</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Test pan tare and final mass</td>
<td>Balance</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Test pan area</td>
<td>Measuring tape</td>
<td>Area calculated from pan's dimensions</td>
</tr>
<tr>
<td></td>
<td>Material density</td>
<td>Graduated cylinder and balance</td>
<td>Density calculated by dividing mass by volume</td>
</tr>
<tr>
<td>Product application resources</td>
<td>Description of equipment</td>
<td>Recordkeeping</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Labor</td>
<td>Recordkeeping</td>
<td></td>
</tr>
</tbody>
</table>

* These measurements are performed at the time of each application of the product being tested.

Table 6. Test Conditions Documentation Measurements During Verification Test Program

<table>
<thead>
<tr>
<th>Factors to Be Verified</th>
<th>Parameter to Be Measured</th>
<th>Measurement Method</th>
<th>Frequency</th>
<th>Program^a</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method of application of product</td>
<td>Amount of water added to product</td>
<td>Recordkeeping</td>
<td>Once/treatment^b</td>
<td>E,F,S</td>
<td></td>
</tr>
<tr>
<td>Application</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Untreated soil properties</td>
<td>Type of soil</td>
<td>USGS</td>
<td>Once^c</td>
<td>E,F,S</td>
<td>Gravels, sands, silts and clays, highly organic soils</td>
</tr>
<tr>
<td>Density</td>
<td>ASTM D-698^30</td>
<td>Once^c</td>
<td>F,S</td>
<td></td>
<td>Mass and volume of sample measured</td>
</tr>
<tr>
<td>Fine and coarse gradation</td>
<td>AASHTO T-21^31</td>
<td>Once^c</td>
<td>F,S</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% crushing</td>
<td>ASTM D-5821^32</td>
<td>Once^c</td>
<td>F,S</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Particle size</td>
<td>ASTM D-4318^33</td>
<td>Once^c</td>
<td>F,S</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Density (sand cone)</td>
<td>ASTM D-1556^34</td>
<td>Once^c</td>
<td>F,S</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plasticity index</td>
<td>ASTM D-4318^35</td>
<td>Once^c</td>
<td>F,S</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area climatic conditions</td>
<td>Wind speed and direction, rainfall, relative humidity, temperature, barometric pressure</td>
<td>Local records of climatic conditions</td>
<td>Continuous</td>
<td>E,F,S</td>
<td></td>
</tr>
<tr>
<td>Factors to Be Verified</td>
<td>Parameter to Be Measured</td>
<td>Measurement Method</td>
<td>Frequency</td>
<td>Program&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Comments</td>
</tr>
<tr>
<td>------------------------</td>
<td>--------------------------</td>
<td>--------------------</td>
<td>-----------</td>
<td>---------------------</td>
<td>----------</td>
</tr>
<tr>
<td>Atmospheric and climatic conditions for site</td>
<td>Ambient temperature</td>
<td>Thermometer</td>
<td>Quarterly&lt;sup&gt;d&lt;/sup&gt;</td>
<td>E,F,S</td>
<td>Only applies when profiling used. Follow Reference&lt;sup&gt;34&lt;/sup&gt;.</td>
</tr>
<tr>
<td></td>
<td>Wind speed and direction</td>
<td>Wind station</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Road surface samples</td>
<td>Silt loading</td>
<td>Dry sieving&lt;sup&gt;36&lt;/sup&gt;</td>
<td>Monthly&lt;sup&gt;e&lt;/sup&gt;</td>
<td>E,F,S</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Moisture content</td>
<td>Weight loss test&lt;sup&gt;32,36&lt;/sup&gt;</td>
<td>Monthly&lt;sup&gt;e&lt;/sup&gt;</td>
<td>E,F,S</td>
<td></td>
</tr>
<tr>
<td>Traffic</td>
<td>Vehicle type; Vehicle weight; Number of axles; Vehicle passes and speed</td>
<td>Periodic visual observation coupled with use of pneumatic traffic counter</td>
<td>Monthly&lt;sup&gt;e&lt;/sup&gt;</td>
<td>E,F,S</td>
<td></td>
</tr>
<tr>
<td>Test section lengths</td>
<td>Length and width</td>
<td>Measuring device</td>
<td>Once&lt;sup&gt;c&lt;/sup&gt;</td>
<td>E,F,S</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup> Program types are dust emissions (E), functional performance (F), and soil stabilization (S).

<sup>b</sup> Measurements will be done once at the time of (and prior to) each application.

<sup>c</sup> Measurements will be done once at the time of (and prior to) the first application.

<sup>d</sup> Quarterly tests occur at the end of each quarter after application. The actual date will be determined by agreement of the parties, and will be dependent upon weather.

<sup>e</sup> Monthly observations will be made at the site, beginning one month after application. The actual date will be determined by agreement of the parties, and will be dependent upon weather.

4.1.4 Measurement Characteristics

The final test factor to be considered is the number, frequency, and duration of measurements to be made. It is recommended that each product be evaluated every 2 to 4 months, totaling four tests within a year; however, shorter tests may be necessary or advisable due to local circumstances. Because some products may have substantially shorter or longer lifetimes, grouping products with similar expected lifetimes along the test road may be important to achieve an efficient test plan. Final grouping of products and frequency of testing will depend on the mix of products being evaluated and will be specified in the T/QAP.

4.1.5 Example Test Schedule

Table 7 presents an example time line for a year-long test program. A shorter program would have fewer performance tests and reapplications.
### Table 7. Test Program Time Line

<table>
<thead>
<tr>
<th>Time Period/Duration (days)(^a)</th>
<th>Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>-30 to -3</td>
<td><strong>Preliminary Activities</strong></td>
</tr>
<tr>
<td></td>
<td>• Stake out test sections and buffer areas</td>
</tr>
<tr>
<td></td>
<td>• Invite manufacturers/vendors to visit site</td>
</tr>
<tr>
<td></td>
<td>• Arrange for road grading or other work (if necessary)</td>
</tr>
<tr>
<td></td>
<td>• Assign section for each product in test</td>
</tr>
<tr>
<td></td>
<td>• Arrange to supply captive traffic (if necessary) to achieve equivalent of 100 to 200 vpd for one week</td>
</tr>
<tr>
<td></td>
<td>• Schedule product applications</td>
</tr>
<tr>
<td></td>
<td>• Arrange for meteorological data from nearby site, if available</td>
</tr>
<tr>
<td>-3 to 0</td>
<td><strong>Product Application</strong></td>
</tr>
<tr>
<td></td>
<td>• Collect initial samples for soil stabilization tests</td>
</tr>
<tr>
<td></td>
<td>• Collect surface samples from each test site</td>
</tr>
<tr>
<td></td>
<td>• Monitor initial application of products by manufacturers/vendors</td>
</tr>
<tr>
<td></td>
<td>• Treat buffer areas with excess products</td>
</tr>
<tr>
<td></td>
<td>• Establish on-site rain gauge and other meteorological instrumentation if necessary</td>
</tr>
<tr>
<td></td>
<td>• Deploy traffic counters</td>
</tr>
<tr>
<td></td>
<td>• Collect product samples</td>
</tr>
<tr>
<td>about 90</td>
<td><strong>Performance Testing over the Test Program(^b)</strong></td>
</tr>
<tr>
<td>about 180</td>
<td>• Conduct first round of quarterly testing followed by product reapplication if desired</td>
</tr>
<tr>
<td>about 270</td>
<td>• Conduct second round of quarterly testing followed by product reapplication if desired</td>
</tr>
<tr>
<td>about 360</td>
<td>• Conduct third round of quarterly testing followed by product reapplication if desired</td>
</tr>
<tr>
<td></td>
<td>• Conduct fourth round of quarterly testing followed by product reapplication if desired</td>
</tr>
</tbody>
</table>

\(^a\) Day 0 occurs when the initial applications of the test products are complete.

\(^b\) Timing of the test series may vary but should be approximately quarterly.

### 4.2 Test Parameters

Verification parameters to consider fall into four categories:

- Performance factors (e.g., percent reduction of dust emissions, functional performance, soil stabilization),
- Associated impacts of using product (e.g., emissions of other pollutants, effects on water quality),
- Associated resource usage (e.g., amount of material used, application labor), and
• Test conditions documentation (e.g., suppressant type, application rate, traffic, climatic conditions).

A verification test will include measurements of uncontrolled dust emissions, road condition, and the dust (PM) CE; functional performance; and stabilization of soil after products are applied to an unpaved road.

Tables 1 through 6 show the performance factor parameters, associated impacts parameters, associated resource usage parameters, and test conditions, respectively, to be measured during a verification test and the measurement method for each parameter (i.e., the standard test method for each parameter, if applicable). The T/QAP will identify the parameters to be measured for the specific product being tested and provide detailed descriptions of measurement methods and procedures and their QC requirements. The verification parameters listed in Tables 1 through 6 will be included in the test report.

Products may be tested for dust (PM) suppression, functional performance, soil stabilization, or a combination of these performance factors. Tables 1 through 6 indicate which parameters should be measured for each of these options.

A mobile dust sampling device on a vehicle will be used to measure relative dust control performance. This sampling device is simply a dust sampler attached to a vehicle that travels along the test section of unpaved road. The cyclone inlet for the mobile sampler is located 2.5 m behind the truck's endgate, and at a height of 1 m above the road surface. An inlet nozzle is used to match sampling intake velocity to the truck travel speed. Test runs for this sampler should consist of replicate measurements for each test section. For each measurement, a specified vehicle should be driven at a constant, specified speed over the test section.

The following conditions need to be met to perform mobile sampling:
• Test roads should allow at least 150 m per test section.
• Test sections should not have a steep grade, sharp curves, or stop-and-go traffic.
• Test sections should not cross draining areas (washes).
• There should be open areas in the immediate vicinity of the test sections on at least one side of the road to permit turnarounds.

The exposure profiling technique may be used in addition to mobile dust sampling to provide data on dust control efficiency. The profiling technique provides direct information on PM emission levels from the road at various times after treatment. The profiling method was used to develop the AP-42 emission factors for unpaved roads. The technique uses multipoint air and meteorological sampling to determine mass flux profiles and associated emission levels. This method requires deployment of a minimum of three particulate samplers and meteorological instrumentation at heights of 1 and 5 m above grade. The multipoint technique utilizes the same isokinetic profiling concept used in conventional stack testing, except that the ambient wind directs the plume to the sampling array. The inherent reliability of this method is tied to the mass balance calculation scheme. The challenge in dealing with fluctuating emissions is met by simultaneously sampling at all specified locations within the plume. A numerical integration
scheme is used to determine the integrated exposure over the effective cross-section of the plume. The emission factor is calculated by dividing the integrated exposure by the measure of the source activity.\textsuperscript{12}

In general, each test run using the exposure profile test method should be long enough so that visible loading is detected on the PM$_{10}$ (particulate matter 10 micrometers or less in aerodynamic diameter) sampling filters. For uncontrolled sections, adequate mass may be achieved with as few as 20 vehicle passes, while 200 to 300 passes may be necessary for controlled sections. The following conditions must be met to perform the profiling:

- Test roads must allow at least 150 m for each test section.
- Test sections should not have a steep grade, sharp curves, or stop-and-go traffic.
- Test sections should not cross draining areas (washes).
- Test sections should be approximately perpendicular to the prevailing daytime wind direction.
- The terrain must be flat and open at least 15 m both upwind and downwind of each test section.

### 5.0 REPORTING AND DOCUMENTATION

This section describes the procedures for reporting data in the verification report and the verification statement, including data type and format (e.g., QA/QC summary forms, raw data collected, photographs/slides/video tapes). The verification report is expected to be about 20 to 40 pages in length and will include the verification statement as an addendum at the front of the report. The verification statement is a two- to five-page summary of the verification results. The verification report, including the verification statement, will be prepared by the testing organization(s). Both documents will be reviewed by APCTVC and the product manufacturer/vendor before being submitted to EPA for review and approval as specified in the ETV QMP.

One verification report will be prepared for each manufacturer/vendor per product, even if the product is tested at multiple sites. An optional “short-term performance” verification report may be prepared halfway through year-long tests (after six months).

#### 5.1 Reports

The testing organization will prepare a verification report that thoroughly describes and documents the verification testing that was conducted and the results of that testing. The report will include the following topics:

- Verification statement, including
  - Verification test description,
  - Description of product and manufacturer/vendor information,
  - Results of the verification test,
  - Brief QA statement, and
  - Signatures of approving authorities;
Introduction;
Description and identification of product tested;
Procedures and methods used in testing;
Statement of product application conditions over which the test was conducted;
Summary and discussion of results:
  ▶ Support for verification statement,
  ▶ Description of associated impacts and resources used,
  ▶ Explanation and documentation of necessary deviations from test plan, and
  ▶ Discussion of QA and QA statement;
References; and
Appendices or separate documents with the following information:
  ▶ QA/QC activities and results,
  ▶ Raw test and laboratory data,
  ▶ Material safety data sheets on the product tested, and
  ▶ Equipment calibration results.

Measurement data are to be presented in a format that allows a reviewer to easily determine whether the testing has met the DQOs.

5.2 Data Reduction

5.2.1 Particulate Emissions Control Efficiency Using the Mobile Dust Sampler

The mass of dust collected during a sampling or blank run is calculated using Equation 1:

\[ M = (W_F - W_T) \]  

Eq. 1

where:
- \( M \) = mass collected (mg),
- \( W_F \) = final mass of the filter (mg), and
- \( W_T \) = tare mass of the filter (mg).

An emission value is determined by dividing the sample mass by the cumulative length of the road traveled by the mobile sampler using Equation 2:

\[ e_m = \frac{M}{D} \]  

Eq. 2

where:
- \( e_m \) = emission value expressed as milligrams per meter of road traveled by the operating sampler (mg/m),
- \( M \) = mass (mg), and
- \( D \) = length of road traveled by the operating sampler (m).

The isokinetic flow ratio (IFR) is the ratio of a directional sampler’s intake air speed to the mean wind speed approaching the sampler. It is given by Equation 3:

\[ IFR = \frac{Q}{aU} \]
where:
\[ Q = \text{volumetric flow rate of the sampler (m}^3/\text{s}), \]
\[ a = \text{sampler intake area (m}^2), \]
\[ U = \text{vehicle speed (m/s)}. \]

This ratio is of interest in the sampling of total particulate, since isokinetic sampling ensures that particles of all sizes are sampled without bias. Specially designed nozzles are available for the high-volume cyclone preseparators to maintain isokinetic (within 20 percent) sampling for wind speeds in the range of approximately 4.5 to 18 m/s (10 to 40 miles per hour [mph]). Because the primary interest in this program is PM$_{10}$ and PM$_{2.5}$ emissions, sampling under moderately nonisokinetic conditions should cause little bias. It is readily recognized that 10 µm (aerodynamic diameter) and smaller particles have weak inertial characteristics at normal wind speeds and therefore are relatively unaffected by anisokinesis.

Measurements of dust suppressant $CE$ is calculated using Equation 4:

\[
CE = 100 \times \frac{(e_{cm} - e_{um})}{e_{um}}
\]

where:
\[ e_{cm} = \text{controlled dust emission value using the mobile source dust sampler, and} \]
\[ e_{um} = \text{untreated dust emission value using the mobile source dust sampler.} \]

5.2.2 Profile Dust Control Efficiency

Calculate the particulate concentration (either total airborne particulate matter or particles equal to or less than 10 micrometers (µm) in aerodynamic diameter) using Equation 5:

\[
Ci = 103 \times \frac{(W_{i,F} - W_{i,T})}{(Q_i \times T_i)}
\]

where:
\[ C_i = \text{concentration (µg/m}^3) \text{ measured by the } i^{th} \text{ sampler,} \]
\[ W_{i,F} = \text{final mass (mg) of the filter used in the } i^{th} \text{ sampler,} \]
\[ W_{i,T} = \text{tare mass (mg) of the filter used in the } i^{th} \text{ sampler,} \]
\[ Q_i = \text{sampling rate (m}^3/\text{hr) of the } i^{th} \text{ sampler, and} \]
\[ T_i = \text{time (hr) of sampling for the } i^{th} \text{ sampler.} \]

Use a conservation of mass approach to determine the particulate exposure or flux from the road (Equation 6). To do this, the upwind particulate concentration is subtracted from the particulate concentration measured at the sampler.

\[
E = 10^{-7} \times C \times U \times T
\]

where:
\[ E = \text{particulate exposure (mg/cm}^2), \]
\[ C = \text{net (i.e., sampler – upwind concentration) concentration (µg/m}^3). \]
\( U = \) approach wind speed (m/s), and
\( T = \) duration of sampling (s).

Integrating the particulate exposure over the effective cross-section of the plume represents the total passage of airborne particulate matter from the road. Equation 7 is used to calculate integrated exposure:

\[
A + \int_0^H Edh
\]

where:
- \( A \) = integrated exposure (m-mg/cm²),
- \( E \) = particulate exposure (mg/cm²),
- \( h \) = height above ground (m), and
- \( H \) = effective plume height above road (m).

Because exposures are measured at discrete heights of the plume, a numerical integration is necessary to determine \( A \). The exposure must equal zero at the bottom and top of the plume. However, the maximum exposure usually occurs below 1 m, so that the exposure decays sharply near the ground. To account for this sharp decay, the value of the exposure at the ground is set equal to the value at 1 m.

The emission factor is determined by dividing the integrated exposure by the number of vehicle passes during sampling using Equation 8:

\[
e = 10^4 * \frac{A}{NVP}
\]

where:
- \( e \) = particulate emission factor expressed in terms of grams per vehicle km traveled (g/VKT),
- \( A \) = integrated exposure (m-mg/cm²), and
- \( NVP \) = number of vehicle passes during a test run.

For the profiler method, the instantaneous control efficiency measured at the time of the test is calculated using Equation 9:

\[
CE + 100 * \left( \frac{e_u - e_c}{e_u} \right)
\]

where:
- \( CE \) = control efficiency (%),
- \( e_u \) = geometric mean untreated dust emission factor for the particle size range of interest (g/VKT), and
- \( e_c \) = measured controlled dust emission factor for the particle size range of interest (g/VKT).
5.2.3 Outlier Identification

The set of uncontrolled emission factors will be checked for outliers using Chauvenet’s criterion. Tabulated in statistical textbooks, this criterion identifies an observation in a sample of size N as an outlier if the probability associated with the difference between the measurement and the mean of the measurements is less than \( \frac{1}{2}N \). As discussed in the background document for AP-42 Section 13.2.2, Unpaved Roads, emission factors are better characterized as log-normally distributed rather than normally (arithmetically) distributed.\(^{36}\) For that reason, the evaluation will be based on logarithms of the emission factors, rather than the emission factors themselves.

5.2.4 Product Application Intensity

The product application intensity is calculated for each sampling pan using Equation 10:

\[
I = 10^4 \times \left( \frac{P_f - P_t}{a_p \cdot \gamma} \right)
\]

Eq. 10

where:

- \( I \) = application intensity for each pan (l/m²),
- \( P_f \) = full pan mass (g),
- \( P_t \) = pan tare mass (g),
- \( a_p \) = top surface area of pan (cm²), and
- \( \gamma \) = density of recovered liquid (g/l).

The density of the liquid is determined from a composite of the product caught in all of the pans, a portion of which is decanted into a graduated cylinder, using Equation 11:

\[
\gamma = \frac{(C_f - C_t)}{V_t}
\]

Eq. 11

where:

- \( \gamma \) = density of liquid (g/l),
- \( C_f \) = full container mass of the graduated cylinder (g),
- \( C_t \) = container tare mass of the graduated cylinder (g), and
- \( V_t \) = volume of liquid in the graduated cylinder (l).

5.2.5 Ambient Temperature

The ambient temperature will be recorded. The average ambient temperature for a test run will be calculated using Equation 12:

\[
\bar{T} = \frac{\sum_{i=1}^{N_T} T_i}{N_T}
\]

Eq. 12

where:

- \( \bar{T} \) = average ambient temperature recorded during a test run (°C),
- \( T_i \) = individual temperature of \( i^{th} \) reading at a recording interval (°C), and
- \( N_T \) = total number of individual temperature readings made during a test run.
5.2.6 Wind Speed

The wind speed will also be recorded. The average wind speed for a test run will be calculated from Equation 13:

$$\bar{U} = \frac{\sum_{i=1}^{N_{WS}} U_i}{N_{WS}}$$

Eq. 13

where:

- $\bar{U}$ = overall mean from 5-minute average wind speeds recorded during a test run (m/s),
- $U_i$ = individual 5-minute average wind speed readings (m/s), and
- $N_{WS}$ = number of individual 5-minute average wind speed readings made during a test run.

5.2.7 Wind Direction

The wind direction will also be recorded. The average wind direction for a test run will be calculated from Equation 14:

$$\bar{D} = \frac{\sum_{i=1}^{N_{WD}} D_i}{N_{WD}}$$

Eq. 14

where:

- $\bar{D}$ = overall mean from 5-minute average wind directions recorded during a test run (degrees from perpendicular to road centerline),
- $D_i$ = individual 5-minute average wind direction readings (degrees from perpendicular to road centerline), and
- $N_{WD}$ = number of individual 5-minute average wind direction readings made during a test run.

5.2.8 Vehicle Passages

During the period of the verification test, some number of vehicles will drive over treated and control sections of the test road. A traffic counter will be used to count the number of vehicle passes. The cumulative vehicle passages assigned to an individual test run will be the average of the total vehicle passages accumulated as calculated from Equation 15:

$$NVP = \left( TC_f - TC_i \right) / 2$$

Eq. 15

where:

- $NVP$ = number of vehicle passes for a test run,
- $TC_f$ = traffic count at the end of a test run, and
- $TC_i$ = traffic count at the beginning of a test run.

Alternatively, visual observations of vehicle passages will be recorded during tests.

5.3 Statistical Analysis of Verification Data

This section describes the statistical analysis of verification data.
5.3.1 Data Quality Calculation

The data quality calculation is described in Appendix A.

5.3.2 Dust Suppressant Control Efficiency

The product’s control efficiency determined for each test run will be plotted against the cumulative number of vehicle passes (CVP) during the test program. Control efficiency will be plotted on the Y-axis, and CVP will be plotted on the X-axis. Then, a regression analysis of control efficiency as a function of CVP will be performed to estimate the decay of the product’s control efficiency. The 95-percent confidence interval to the mean of the data will be calculated. The estimated regression line and the upper and lower 95-percent confidence boundaries will be displayed on the graph. Where the lower 95-percent confidence boundary is extrapolated to the intersection with 0 percent control efficiency provides an estimate of where the product’s effectiveness has vanished, as a function of CVP.

An example data set is provided in Table 8. The control efficiency as a function of CVP is presented in Figure 1. The estimated control efficiency decay is presented as the regression line.

Table 8. Product Performance Data

<table>
<thead>
<tr>
<th>Days After Treatment</th>
<th>Vehicle Passes After Treatment</th>
<th>PM$_{10}$ Control Efficiency (%)</th>
<th>Total Suspended Particulate (TSP) Control Efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>2750</td>
<td>98.4</td>
<td>88.2</td>
</tr>
<tr>
<td>12</td>
<td>3000</td>
<td>97.4</td>
<td>78.2</td>
</tr>
<tr>
<td>26</td>
<td>6500</td>
<td>90.8</td>
<td>50.3</td>
</tr>
<tr>
<td>28</td>
<td>7000</td>
<td>85.6</td>
<td>46.6</td>
</tr>
</tbody>
</table>
6.0 DISSEMINATION OF VERIFICATION REPORTS AND STATEMENTS

After a product has been tested and the report and verification statement received from the testing organization, a draft of both will be sent to the manufacturer/vendor for review before APCTVC releases them to EPA for review and approval prior to public dissemination. This gives the manufacturer/vendor an opportunity to review the information on the company and product, the results, test methodology, and report terminology. The manufacturer/vendor may submit comments on the statement and report to APCTVC, who will consider these comments and revise the report as appropriate.

After final review by the manufacturer/vendor and review by APCTVC, the verification report and statement will be submitted to EPA for review and approval. Several copies of the approved verification report (one bearing original signatures on the verification statement, if appropriate) will be provided to the manufacturer/vendor. Distribution, if desired, is at the manufacturer’s/vendor’s discretion and responsibility. Signed verification statements and reports will be posted on the ETV web site (http://www.epa.gov/etv) for public access without restriction.
7.0 REQUIREMENTS FOR THE T/QAP

7.1 Quality Management

All testing organizations participating in the Dust Suppression and Soil Stabilization Technology Program must meet the QA/QC requirements defined below and have an adequate quality system to manage the quality of work performed. Documentation and records management must be performed according to the ETV QMP or its successor plan in effect at the time of testing. Testing organizations must also perform assessments and allow audits by APCTVC (headed by the APCTVC QA Manager) and EPA corresponding to those in Section 8.0.

All testing organizations participating in the Dust Suppression and Soil Stabilization Technology Program must have an ISO 9000-accredited or ANSI/ASQ E4-compliant quality system and an EPA- or APCTVC-approved QMP.

7.2 Quality Assurance

All verification testing will be done following an approved T/QAP that meets EPA Requirements for Quality Assurance Project Plans, EPA QA/R-5 and Part B, Section 2.2.2 of EPA’s ETV QMP or its successor plan in effect at the time of testing. These documents establish the requirements for T/QAPs, and the common guidance document, Guidance for Quality Assurance Project Plans, EPA QA/G-5, provides guidance on how to meet these requirements. RTI’s APCT QMP implements this guidance for APCTVC. The T/QAP must describe how this GVP will be implemented by the testing organization and the steps the testing organization will take to ensure acceptable data quality in the test results. Any needed standard operating procedures (SOPs) will be developed in accordance with Guidance for the Preparation of Standard Operating Procedures (SOPs) for Quality Related Documents, EPA QA/G-6.

The testing organization (e.g., MRI) must prepare a T/QAP and submit it for review by APCTVC. EPA must review and approve the T/QAP before the test organization can begin verification testing.

7.3 Additional Requirements to be Included in the T/QAP

The testing organization (e.g., MRI) must prepare a T/QAP and submit it for review by APCTVC. A separate plan will be developed for each test site for a specific series of tests. The plans must comply with EPA QA/R-538. EPA will review and approve the plan. The plan must be approved by EPA before the test organization can begin verification testing.

The T/QAP must include a schematic of all sampling and test locations. It must also include appropriately detailed descriptions of all measuring devices that will be used during the test. These measurements are expected to include those listed in Tables 1 through 6.

The T/QAP must describe all techniques to be used for monitoring road and weather conditions. It must also note the techniques that will be used to obtain any other operational parameters.
8.0 ASSESSMENT AND RESPONSE

APCTVC and/or EPA will conduct assessments to determine the testing organization’s compliance with its T/QAP. The requirement to conduct assessments is specified in EPA’s QMP and in RTI’s APCT QMP or their successors. The APCT QMP will be revised after the revised ETV QMP is approved. EPA will assess RTI’s compliance with RTI’s T/QAPs. RTI will assess the compliance of other organizations with their T/QAPs. The assessments will be conducted according to Guidance on Technical Audits and Related Assessments for Environmental Data Operations, EPA QA/G-71.

8.1 Assessment Types

**Technical systems audit (TSA)** – Qualitative on-site audit of the physical setup of the test and determination of whether testing personnel are in compliance with the T/QAP.

**Performance evaluation audit (PEA)** – Quantitative audit in which measurement data are independently obtained and compared with routinely obtained data to evaluate the accuracy (bias and precision) of a measurement system.

**Audit of data quality (ADQ)** – Qualitative and quantitative audit in which data and data handling are reviewed and data quality and data usability are assessed. At least 10 percent of the verification data must be checked.

**Assessment of the quality system** – Qualitative assessment of a particular quality system to establish whether the prevailing quality management structure, policies, practices, and procedures meet EPA requirements and are adequate for ensuring that the type and quality of data needed are obtained. The assessment can be performed by an internal assessor (self-assessment) or an external assessor (independent assessment).

8.2 Assessment Frequency

Activities performed during product verification performance operations that affect the quality of the data shall be assessed regularly, and the findings reported to management to ensure that the requirements stated in the GVPs and the T/QAPs are being implemented as prescribed.

The types and minimum frequency of assessments for the ETV are listed in Part A, Section 9.0 of EPA’s Environmental Technology Verification Program Quality Management Plan. Tests conducted by or for APCTVC will have at a minimum the following types and numbers of assessments:

1. **TSA** – self-assessments for each test as provided for in the T/QAP and independent assessments, twice for APCTVC.
2. **PEA** – self-assessments, as applicable, for each test as provided in the T/QAP and independent assessments, as applicable for each different product verified by APCTVC.
3. **ADQ** – self-assessments of at least 10 percent of the verification data and independent assessment, as applicable, for APCTVC.
Independent assessments of tests conducted by RTI will be performed by EPA. Independent assessments of other organizations will be conducted by RTI.

8.3 Response to Assessment

Appropriate corrective actions shall be taken and their adequacy verified and documented in response to the findings of the assessments. Data found to have been taken from nonconforming products shall be evaluated to determine its impact on the quality of the data. The impact and the action taken shall be documented. Assessments are conducted according to procedures contained in the APCTVC’s QMP. Findings are provided in audit reports. Responses to adverse findings are required within 10 working days of receiving the audit report. Follow-up by the auditors and documentation of responses are required.

9.0 SAFETY MEASURES

9.1 Safety Responsibilities

The testing organization’s field team leader is responsible for ensuring compliance with site entry, health, and safety requirements. Although the field team leader is responsible, each individual staff member is expected to follow the requirements and report to the field team leader personnel who deviate from them so corrective actions may be taken.

9.2 Safety Program

The testing organization must maintain a comprehensive safety program that all field personnel must read and follow. In addition, field personnel are expected to familiarize themselves with the site safety practices. If required by the site operator, field personnel will attend a safety orientation with the site safety officer. Before or on the first day onsite, the test organization’s field team leader will fill out an Emergency Response Procedure form, discuss it with test team members, and post it at a place or places accessible to all test team work stations. The form will include as a minimum the following information:

- Procedures for obtaining emergency medical assistance,
- Location of first aid station(s) and emergency equipment, and
- Location and directions to local hospital(s).

9.3 Safety Requirements

All test personnel will adhere to the following general safety requirements:

- Confine themselves to authorized areas only,
- Wear protective glasses or goggles and headgear at all times where designated,
- Wear steel-toed boots/shoes where designated,
- Wear hearing protection at all locations where designated, and
- Wear other personal protective equipment as required and/or specified in the T/QAP.
10.0 REFERENCES


   - EPA Test Method 1003.0, Green Alga, Selenastrum Capricornutum, Growth Test. Section 14, pp. 181-211.


   - Method 1311, TCLP - Toxicity Characteristics Leaching Procedure
   - Method 6010, Inorganics by ICP
   - Method 8260, VOCs by GC/MS
   - Method 8270, SVOCs by GC/MS


30. ASTM. (2000). *D698-00a, Standard Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort [12,400 ft-lb/ft³ (600 kN-m/m³)]*. West Conshohocken, PA: ASTM.


34. ASTM. (2000). *D1556-00, Standard Test Method for Density and Unit Weight of Soil in Place by the Sand-Cone Method*. West Conshohocken, PA: ASTM.


APPENDIX A – MOBILE SAMPLER QC CRITERIA AND DQO

Calculation of Confidence Intervals for Quarterly Control Efficiencies

A preliminary study was conducted at Fort Leonard Wood (FLW) from October 2001 to January 2002 using the mobile sampler to measure the control efficiency of dust suppressants. The calculation of confidence intervals for an efficiency, $CE_t$, was accomplished by first deriving an algebraic expression that approximates the variance of $CE_t$ in terms of the component means, variances, and sample sizes:

$$\text{Var}[CE_t] = \text{Var}[1 - \frac{\bar{X}_t}{\bar{X}_0}] = \text{Var}[\frac{\bar{X}_t}{\bar{X}_0}]$$

$$\approx \frac{1}{\bar{X}_0^2} \left[ \text{Var}[\bar{X}_t] + \frac{\bar{X}_t^2}{\bar{X}_0^2} \text{Var}[\bar{X}_0] \right]$$

$$= \frac{\bar{X}_t^2}{\bar{X}_0^2} \left[ \left( \frac{RSD_t^2}{n_t} \right) + \left( \frac{RSD_0^2}{n_0} \right) \right]$$

$$= \left(1 - CE_t\right)^2 \left[ \left( \frac{RSD_t^2}{n_t} \right) + \left( \frac{RSD_0^2}{n_0} \right) \right]$$

Eq. 1

where:
- $\bar{X}_t$ denotes the mean of $n_t$ post-treatment observations,
- $\bar{X}_0$ denotes the mean of $n_0$ pre-treatment (baseline) observations, and
- $RSD_t$ and $RSD_0$ denote the relative standard deviations for the post-treatment and baseline observations, respectively.

In the preliminary study, the sample sizes were 2 for the post-treatment observations and 3 for the baseline observations. The above derivation makes use of a Taylor series approximation. The means and standard deviations of the duplicate measurements (and the time 0 triplicates) were then computed and plotted. These plots clearly showed that standard deviations increased as the (mean) levels increased. It appeared that a relationship of the form $s=Bx$ between the standard deviation ($s$) and the mean ($x$) would adequately approximate the variance of the measurements (i.e., a model that assumes that the $RDS=s/x$ is constant, and equal to $B$). Substitution of this model into the above variance expression for $CE_t$ leads to

$$\text{Var}[CE_t] \approx \left(1 - CE_t\right)^2 \hat{B}^2 \left[ \frac{1}{n_t} + \frac{1}{n_0} \right]$$

Eq. 2

where $\hat{B}$ is the estimate of $B$.

In the previous study, three different estimates of $B$ were considered: the geometric mean of the relative standard deviations ($RDS$s), the median of the $RDS$s, and the mean of the $RDS$s. For estimating $B$, cases in which a duplicate had a zero measurement (either one or both) were not used. The estimate based on the geometric mean was recommended. (It is less sensitive to large $RDS$s than the third method, and can be derived from the least squares estimate for $\log(B)$ in the model $\log(s)= \log(Bx)$; this log-scale model has appeal because it should have fairly
homogeneous error structure—since standard deviations of standard deviations tend to increase proportionally with their magnitude.) Estimates of B from the prior study were 0.163 for PM\(_{10}\), 0.176 for PM\(_{2.5}\), and 0.150 for total particulates.

Forming a confidence interval for a quarterly CE in future verification tests can be accomplished in two ways. The first way assumes the following:

1. A model like that used in the prior study (i.e., s=Bx) will be used to produce an estimate of B, and
2. The estimate of B is used, along with the CE\(_t\) value, to produce the estimated variance of CE\(_t\) via Equation 2.

Then a 90% confidence interval would be formed via

\[
CE_t \pm t_{k,0.95} \sqrt{Var[CE_t]}
\]

Eq. 3

Where \( t_{k,0.95} \) is the upper 95th percentile of the t distribution with k degrees of freedom. The degrees of freedom, k, can be taken to be equal to the number of RDSs upon which the estimated B is based. Hence, this first approach will be useful only after a substantial amount of testing has been performed. In this context, the subscripts \( t \) and \( \theta \) in the above equations now represent something different than they did in the preliminary study. In that study, as noted above, the \( \theta \) subscript represented a baseline, pre-treatment condition for a given road segment and \( t \) represented that same segment after treatment (of a given type); in the planned study, the \( \theta \) subscript identifies measurements for an untreated segment at a given point in time and the \( t \) subscript identifies measurements on a similar segment at that same point in time that was treated with product \( t \).

The second way of forming a confidence interval for a CE does not rely on the variance versus mean model; rather it uses only the data from \( n_t + n_\theta \) observations used in calculating the CE\(_t\). In this case, Equation 1 [last part] is used to compute the variance of the control efficiency and the 90% confidence interval is determined as:

\[
CE_t \pm t_{k,0.95} \sqrt{Var[CE_t]}
\]

Eq. 4

where \( t_{k,0.95} \) is the upper 95th percentile of the t distribution with k degrees of freedom. The degrees of freedom, k, in this case, is determined (after rounding the result down to the nearest integer) by Satterthwaite’s formula:

\[
K = \frac{\left(\frac{RSD_t^2}{n_t} + \frac{RSD_\theta^2}{n_\theta}\right)^2}{\left(\frac{RSD_t^2}{n_t}\right)^2 + \left(\frac{RSD_\theta^2}{n_\theta}\right)^2}
\]

Eq. 5

This approach for forming confidence intervals can be implemented early in the testing. The value of k will tend to be maximized if the RSDs and the ns are the same; in that case, \( k = n_t + n_\theta - 2 \).
The formation of confidence intervals in either of the above two ways assumes that the estimated quarterly efficiencies are approximately normally distributed. The former way (Equation 3) also relies on the accuracy of the variance-versus-mean relationship. The former way also has the advantage that the estimation of the B can make use of data from all of the different treatments used in a study. For example, if five products are tested at each of four quarters, there will be 6x4 standard deviations that can be used in the modeling.

**Anticipated Half-Widths of Confidence Intervals for Quarterly Control Efficiencies**

The values of B obtained in the prior study can be used to provide some insight into the expected widths of the confidence intervals. If the estimated B is taken to be the true RDS value for the planned study, and if a sample size of 5 is used, then the observed RDSs would be expected, with approximately 95% confidence, to fall between 0.35B and 1.67B. (This is based on a chi-square distribution with 4 degrees of freedom.)

Values of the RDSs appearing in Equation 1 were allowed to take on various multiples of B as shown in Table A-1:

**Table A-1. Values for RDSs.**

<table>
<thead>
<tr>
<th>Selected values of RDSs</th>
<th>Description of RDS Values</th>
<th>Ratio of RDSs</th>
<th>( k ) determined from Eq. 5</th>
<th>( t_{k,0.95} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.35B and 0.35B</td>
<td>Both values near lower end of expected range</td>
<td>1.00</td>
<td>8</td>
<td>1.86</td>
</tr>
<tr>
<td>0.35B and 1.00B</td>
<td>One value near lower end, one near expected value</td>
<td>2.86</td>
<td>4</td>
<td>2.13</td>
</tr>
<tr>
<td>0.35B and 1.67B</td>
<td>One value near lower end, one near upper end of expected range</td>
<td>4.77</td>
<td>4</td>
<td>2.13</td>
</tr>
<tr>
<td>1.00B and 1.00B</td>
<td>Both values near expected value</td>
<td>1.00</td>
<td>8</td>
<td>1.86</td>
</tr>
<tr>
<td>1.00B and 1.67B</td>
<td>One value near expected value, one near upper end of expected range</td>
<td>1.67</td>
<td>6</td>
<td>1.94</td>
</tr>
<tr>
<td>1.67B and 1.67B</td>
<td>Both values near upper end of expected range</td>
<td>1.00</td>
<td>8</td>
<td>1.86</td>
</tr>
</tbody>
</table>

Table A-2 provides half-widths of 90% confidence intervals for CE generated for four different B values ranging from 0.15 to 0.30 and for seven different efficiencies ranging from 40% to 95%. These were combined with the four choices for B and the seven efficiency values to produce the estimated half-widths. Equation 1 was used to produce the variance estimate, Equation 5 was used to determine \( k \), and the half-width was determined as indicated in Equation 4.

**QC Criteria for Quarterly Test Runs**

The analysis above provides an estimate for quantitative QC criteria for the five replicate measurements that comprise a test run during the quarterly tests. The estimated criteria are to achieve an RDS for a test run of 0.334 or less. This is based on a value of B=0.2. This value was
chosen a little above the values of B obtained in the preliminary study because there are no data to assess how test site conditions from test to test may affect the value of B. The above analysis shows that, with 95% confidence, actual RDSs are estimated to be between 0.35B and 1.67B; thus, the criteria are set at less than the upper end (RDS of 0.334). The RDS is calculated (for a given product or uncontrolled segment at a given time) as:

\[
RSD = \sqrt{\frac{\sum_{i=1}^{5} X_i^2 - 5\overline{X}^2}{4}}
\]

Eq. 6

where:

- \(X_i\) = \(i^{th}\) measurement (\(i=1,2,...,5\)) for the given product (or uncontrolled segment), and
- \(\overline{X}\) = mean of 5 measurements.

**Calculation of Confidence Intervals for Annual Control Efficiencies**

Assume that the annual control efficiency for a given product is estimated as:

\[
A_t = \frac{1}{4} \sum_q CE_{tq} = 1 - \frac{1}{4} \sum_q \left( \frac{\overline{X}_{tq}}{\overline{X}_{0q}} \right)
\]

Eq. 7

where:

- the index \(q\) denotes quarters (\(q=1,2,3,4\)),
- \(CE_{tq}\) is the estimated control efficiency for quarter \(q\) and treatment \(t\),
- \(\overline{X}_{tq}\) denotes the quarterly mean of observations for quarter \(q\) and treatment \(t\), and
- \(\overline{X}_{0q}\) denotes the quarterly mean of observations for quarter \(q\) and treatment 0, the uncontrolled segment.

If Equation 2 is used to estimate the variance of the quarterly control efficiencies, then the variance of the annual estimate is given approximately as

\[
Var[A_t] \approx \frac{\hat{B}^2}{8n} \left[ \sum_q (1 - CE_{tq})^2 \right]
\]

Eq. 8

Equation 8 assumes the sample size is \(n\) for each quarter and treatment (\(n\) is expected to be 5). The degrees of freedom, \(k\), associated with Equation 8 can be taken to be equal to the number of RDSs upon which the estimated \(B\) is based. Then a 90% confidence interval for an annual control efficiency for product \(t\) would be formed as

\[
A_t \pm t_{k,0.05} \sqrt{Var[A_t]}
\]

Eq. 9

where \(t_{k,0.05}\) is the upper 95th percentile of the \(t\) distribution with \(k\) degrees of freedom.
DQO for Annual CE

Half widths of confidence intervals for annual CE, as determined via Equation 9, should be approximately ½ as long as those expected for quarterly CE (see Table A-2). This can be seen by assuming that the CE values that appear in Equation 8 are the same for all four quarters; simplification of Equation 8 then results in a variance that is ¼ as big as that given by Equation 2—that is, the resultant confidence intervals will be ½ as long. This rationale provides an appropriate approach for defining a DQO, since no prior annual data exists as a basis for such a DQO.

Using the above assumptions and assuming that the quarterly RDS criteria are met for each set of five replicate measurements, a DQO for the annual CE measurement can be set consistent with the quarterly criteria. The DQO is expressed as the half-width interval for the 90% confidence limits and is set at ½ the value in Table A-2 for a B of 0.2 and RDS/B of 1.67. For example, the DQO is 1% when the CE is 95% or 12% when the CE is 40%.

The DQO for shorter test periods is adjusted relative to the amount of data available. For example, half-widths of confidence intervals for 6-month CE should be approximately 70% as long as those expected for quarterly CE, versus ½ as long for annual CE. In this case the DQO is 1.4% when the CE is 95% or 17% when the CE is 40%.
Table A-2. Half Widths of Confidence Intervals for Control Efficiency (CE) for Selected Combinations of RDSs and Estimated Efficiencies (%)

<table>
<thead>
<tr>
<th>B</th>
<th>Smaller RDS/B</th>
<th>Larger RDS/B</th>
<th>Ratio of RDSs</th>
<th>Smaller RDS</th>
<th>Larger RDS</th>
<th>Half-Widths of 90% Confidence Intervals for CEs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CE_{95}%</td>
</tr>
<tr>
<td>0.15</td>
<td>0.35</td>
<td>0.35</td>
<td>1.00</td>
<td>0.053</td>
<td>0.053</td>
<td>0.3</td>
</tr>
<tr>
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<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>0.150</td>
<td>0.150</td>
<td>0.9</td>
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<td>1.67</td>
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<td>0.251</td>
<td>0.150</td>
<td>0.251</td>
<td>1.5</td>
</tr>
<tr>
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<td>1.67</td>
<td>1.67</td>
<td>0.150</td>
<td>0.150</td>
<td>0.150</td>
<td>1.3</td>
</tr>
<tr>
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<td>1.00</td>
<td>2.857</td>
<td>0.053</td>
<td>0.150</td>
<td>0.150</td>
<td>0.8</td>
</tr>
<tr>
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<td>1.67</td>
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<td>0.053</td>
<td>0.251</td>
<td>0.251</td>
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<td>0.070</td>
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<td>0.200</td>
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<td>0.300</td>
<td>0.300</td>
<td>0.300</td>
<td>1.8</td>
</tr>
<tr>
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</tr>
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<td>0.300</td>
<td>0.501</td>
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<td>2.5</td>
</tr>
<tr>
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